

High Resolution CO Images of Seyfert Galaxies

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One of the current problems in research on active galaxies is to determine to what degree one can separate Seyfert and starburst activity. It has been suggested that these two phenomena are related in an evolutionary sense (Norman and Scoville 1988; Weedman 1983) and N-body simulations have been performed to demonstrate this possibility in the case of interacting galaxies (Hernquist 1989). In this study, we investigate the role of molecular gas in fueling the activity in three Seyfert nuclei.

The Berkeley-Illinois-Maryland millimeter array (BIMA) has been used to image the ^{12}CO ($J=1-0$) emission of three relatively close (12-64 Mpc) Seyfert 1 galaxies, NGC 3227, NGC 7469 and NGC 5033, chosen for their strong single dish CO detections (Heckman *et al.* 1989). Extensive $u-v$ coverage was obtained for all three galaxies resulting in $2''$ - $3''$ resolution.

The integrated intensity images of CO emission in NGC 3227, overlaid on $\text{H}\alpha$ emission, and in NGC 7469, overlaid on red continuum, are shown in figures 1 and 2 respectively. The CO emission in NGC 3227 and NGC 7469 appear as compact structures with respective scale sizes of 1.2 and 5 kpc, centered on the active nuclei, and containing substantial fractions ($\sim 80\%$ and $\sim 50\%$) of the single dish flux. The CO emission in NGC 5033 is not detected at such high resolution, implying a CO structure size of $20''$ - $60''$ (1.2-3.6 kpc). Table 1 lists the integrated CO fluxes and comparison single dish measurements.

The H_2 masses (Table 1) are estimated using the $\text{N}(\text{H}_2)/\text{I}(\text{CO})$ conversion factor, $2.5 \times 10^{20} \text{ H}_2 \text{ cm}^{-2} (\text{K km s}^{-1})^{-1}$ (Bloemen *et al.* 1986), that was derived from Galactic giant molecular clouds. As a comparison, the dynamical masses (Table 1) were computed assuming a gravitationally bound rotating disk model ($M = v^2 R/G$), which is consistent with the kinematics of the gas. The estimated H_2 masses for both NGC 3227 and NGC 7469 are a rather large fraction of the dynamical mass. In fact the H_2 mass for the unresolved component of NGC 7469 is comparable to the dynamical mass. This result is improbable because we know that stars, which are concentrated towards the galactic center, contribute to the mass. In light of recent theoretical and observational studies of the $\text{N}(\text{H}_2)/\text{I}(\text{CO})$ ratio, the CO luminosity seems to be enhanced resulting in an overestimate of the H_2 mass if the "standard" conversion factor is applied (Maloney and Black 1988; Crawford *et al.* 1985).

The blue- and red-shifted CO emission in NGC 3227 (fig. 3) and in NGC 7469 (fig. 4) are shown overlaid at a lower ($\sim 5''$) resolution. In both cases, the displacement between the blue and red peaks is along the major axis and the gas moves in the same sense as rotation curves determined for the galaxies (NGC 3227: Rubin and Ford 1968, NGC 7469: Wilson *et al.* 1986) supporting the idea that the molecular gas has rotational motion about the nucleus. In the case of NGC 7469, this result confirms that the molecular gas is involved with the starburst component.

The results of this study are consistent with the scenario that interacting galaxies cause gas to concentrate in the nucleus thereby feeding starburst and Seyfert activity. Both Seyferts with high central concentrations of CO emission, NGC 3227 and NGC 7469, are interacting galaxies listed in Arp's catalogue (Arp 1966) as Arp 94 and Arp 298 respectively. Both of the galaxies are also known to have some starburst component (Kirkpatrick 1989; Wilson *et al.* 1986). The third Seyfert, NGC 5033 has no

detectable centrally concentrated gas emission implying either an alternate mechanism of feeding the central blackhole or perhaps an exhaustion of the molecular gas fuel.

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TABLE 1
RESULTS

	NGC 3227	NGC 7469	NGC 5033
Source size, maj. axis (kpc)	1.2	5	...
ΔV_{CO} (km s ⁻¹)	400 ± 30	310 ± 30	...
BIMA			
Integrated CO Flux (Jy km s ⁻¹)			
BIMA	470 ± 140	320 ± 70	$< 40^b$
NRAO ^a	600	660	440
% NRAO detected by BIMA	80 ± 20	50 ± 10	< 10
H_2 mass ($10^9 M_\odot$)			
Total	2	20	< 0.08
Unresolved Component	0.6	6	...
Dynamical mass ($10^9 M_\odot$)			
Total	10	30	...
Unresolved Component	3	5	...

^aBlitz *et al.* 1986 and Heckman *et al.* 1989

^bunits are Jy km s⁻¹/3"beam

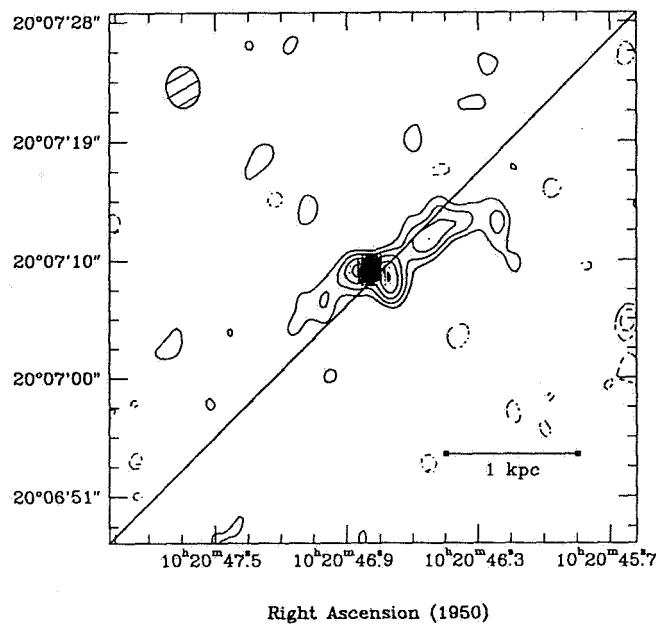


Fig. 1 NGC 3227: Total CO intensity contours overlaid on H α .

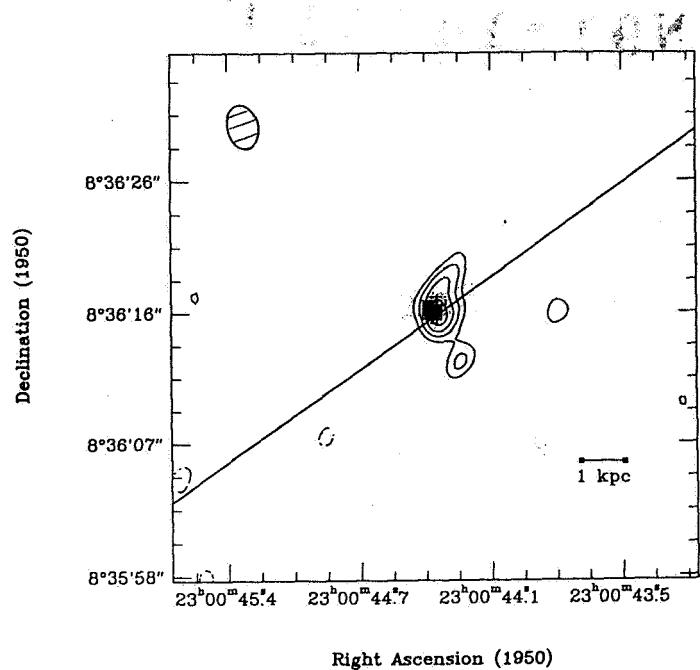


Fig. 2 NGC 7469: Total CO intensity contours overlaid on red continuum.

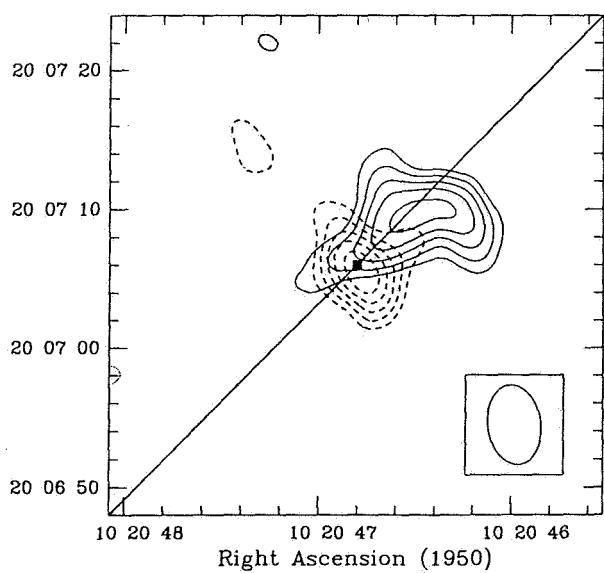


Fig. 3 NGC 3227: Blue-shifted (solid) and red-shifted (dashed) CO.

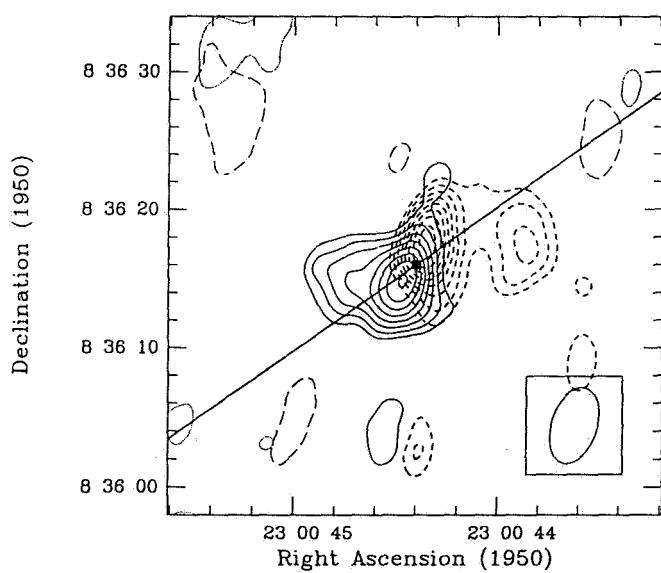


Fig. 4 NGC 7469: Blue-shifted (solid) and red-shifted (dashed) CO.